GARRAD
HASSAN

REVIEW OF OFFSHORE WIND FARM PROJECT FEATURES

Client	**US Army Corps of Engineers**
Contact	Karen K. Adams
Document No	3729/BR/01
Issue No	A
Status	FINAL
Classification	Client's Discretion
Date	30 July 2003

Author:

C A Morgan, P G Hodgetts, W W Schlez, C J A Versteegh

Checked by:

C A Morgan

Approved by:

A D Garrad

DISCLAIMER

Acceptance of this document by the client is on the basis that Garrad Hassan and Partners Limited are not in any way to be held responsible for the application or use made of the findings of the results from the analysis and that such responsibility remains with the client.

Key To Document Classification

Strictly Confidential	:	Recipients only
Private and Confidential	:	For disclosure to individuals directly concerned within the recipient's organisation
Commercial in Confidence	:	Not to be disclosed outside the recipient's organisation
GHP only	:	Not to be disclosed to non GHP staff
Client's Discretion	:	Distribution at the discretion of the client subject to contractual agreement
Published	:	Available to the general public

Revision History

Issue No:	Issue Date:	Summary
A	30 Jul 03	Original final report

Circulation:	Copy No:
GH Bristol	1
GH Glasgow	2
Client	3 - 4

Copy No: _____

CONTENTS

1 INTRODUCTION

1.1 Background

US Army Corps of Engineers (USACE) has contacted Garrad Hassan and Partners Limited (GH) to provide an overview of the state-of-the-art of the development of offshore wind farms, specifically in relation to the site environment.

This work has been undertaken to the specification of USACE who are undertaking an environmental impact assessment of the proposed CWA offshore wind farm development at Horseshoe Shoal, Nantucket Sound, USA.

1.2 Objectives

USACE have defined the following objectives[1] :

- Provide a written analysis of the "state of the art" for offshore wind addressing whether and how the construction and operation is affected by water depth and wave conditions.

- Assess what advances are anticipated in this area in the next 2 to 3 years.

The above were to be achieved through a review of existing offshore wind farm projects and all projects anticipated to be constructed in the reasonably foreseeable future. The review was to gather key project and site parameters, primarily for comparison to those at the Horseshoe Shoal project, Nantucket, which is currently being assessed by USACE.

[1] Email from Karen K Adams, USACE, to Colin Morgan, GH, 26 June 2003.

2 APPROACH

2.1 Identification of sites to be surveyed

There are currently approximately 500 MW of offshore wind power in operation with approximately 300 MW in construction or contracted to be constructed over the next year. However, there are project plans for offshore farms totalling several thousand megawatts some of which are well-defined and others which are only at pre-feasibility study stage. The first stage of this study was to identify those projects which should form the basis of this review. GH selected all sites which were judged to fall into one of the following categories:

- Wind farms which entered commercial operation in 2000 to 2002, inclusive, which now represent proven technology (5 sites, totalling 224 MW).

- Wind farms which are in construction currently or which are under contract to be constructed in the next year (6 sites, totalling 336 MW), seen as being on the cutting edge of offshore wind development.

- Wind farm proposals which are very well-advanced in terms of development rights, consents and which have a promising market for their output, but which have yet to receive economic sanction to allow construction contracts to be placed (12 sites, totalling approximately 1500 MW). As a result of this definition, wind farms in this category mostly have commercial operation commencing in 2005, with some in 2004 and some in 2006.

The identification of sites falling into the last category is somewhat subjective. It has to be expected that some of the projects identified will not be realised in the time stated, while other projects, not listed in this report, will be constructed in 2005 or 2006. However, the sites identified here are considered to give a good overview of the state-of-the-art in terms of project characteristics and parameters.

It can be seen that all the projects listed are in Northern Europe (UK, Germany or Netherlands). GH has considered all global markets but consider that, with the possible exception of Horseshoe Shoal, Nantucket, none of the projects elsewhere clearly fall within the above categories.

2.2 Parameters surveyed

The parameters of interest to USACE and which have been considered by GH, have been tabulated, as requested by USACE.

2.3 Information gathering

Data have been primarily collected from public domain sources such as websites and environmental impact statements. GH has also used in-house, non-confidential, data such as that gathered during site visits. However, some project developers have also been approached to add missing detail to the review. The main sources are cited in Tables 1 to 4.

2.4 Accuracy

Given the varied sources of information and the early stage of many of the developments which have not yet been contracted, some of the data presented are approximate in nature. GH has attempted throughout to collate the data in a comparable form and also to state the accuracy of the data in Tables 1 to 4.

3 PRESENTATION OF RESULTS

The results of the survey are presented in tabular form in Tables 1 to 4 as follows:

Table 1: Operational projects built 2000 to 2002
Table 2: Projects being constructed during 2003 or under contract for construction
Table 3: Projects to be constructed 2004 to 2006 but not yet contracted
Table 4: CWA Nantucket Horseshoe Shoal wind farm (for comparison)

In these tables, "Not available" typically means that GH has not been able to identify the data, even after contacting the project owner or developer.

Figure 1 shows the approximate locations of the wind farms identified.

Figure 1 Approximate locations of sites identified.

4 DISCUSSION

In this section there is general discussion of each of the site or project characteristics surveyed.

4.1 Project and wind turbine maximum output

The wind farm and wind turbine unit rated power have been listed. It should be noted that for future projects in which the turbine selection or the turbine specification has not been finalised, this figure is approximate or within the range stated.

4.2 Mean wind speed

The long-term annual mean wind speed has been listed for each project, where possible. The reference height for this measurement has been stated where possible, unless it was not available in the source data in which case it can typically be assumed to be at the wind turbine hub height.

As site wind speeds are commercially-sensitive, many developers do not publicise the data for their site and for those situations, GH has used a published offshore wind atlas produced by Garrad Hassan and Germanischer Lloyd (referred to as "GH/GL" in the tables)[2] for the waters around European Union countries (as of 1995).

4.3 Water depth

Water depth has been listed, for the shallowest and deepest proposed turbine locations, at lowest astronomical tide (LAT). This information has been supplemented with the tidal range, as some sites have quite a high range, which is an important factor in substructure design.

4.4 Extreme conditions

The 50-year extreme significant wave has been listed (except where noted otherwise). This is a factor in the substructure design for all projects. The associated maximum wave height (peak to trough) is 1.86 times the value shown.

The ice loading on the substructure is also a factor, where noted, for some Baltic Sea sites.

It should also be noted that structural design shall take account of fatigue loading due to a combination of wave and wind speeds and of extreme wind loads. However, none of these factors lend themselves to simple categorisation or identification.

4.5 Substrate type

The nature of the seabed and underlying substrates has been listed. Information on this subject has been highly variable from project to project. Some projects have made public the findings of detailed site surveys while others have yet to complete or publish such information.

It is also noted that it is not straightforward to deduce from a description of the substrate whether one site is more onerous or costly to construct than another. For example:

---

[2] H G Matthies, A D Garrad et al, "Study of Offshore Wind Energy in the European Community", European Commission Contract No. JOUR-0072.

- A site with homogeneous sand substrates may lend itself to a driven monopile foundation, whereas a shallow rock substrate may lend itself to a drilled and grouted monopile foundation. Typically, the latter would be significantly smaller in design and have lower procurement cost but its installation cost would be higher.

- Alternatively, a sandy substrate which offers poor load bearing, high mobility and/or obstruction risk may offer something close to a worst case scenario for foundation design.

4.6 Structure foundation type

The foundation concept has been listed to the extent that it is available although it is not normally finalised until the construction contractor has been selected.

4.7 Distance to land fall and interconnection with the transmission grid

The distance to nearest land fall and interconnection with the transmission grid have been listed. The interconnection on the recent large Danish projects (Nysted and Horns Rev) is in on the wind farm site as the utility network has been extended to include an offshore transformer substation.

4.8 Type of transmission line

The voltage of the transmission line between wind farm and shore has been listed. Although DC transmission exists as a proven engineering concept, all of the wind farms selected are likely to use conventional AC transmission.

4.9 Operation & Maintenance issues relating to environmental conditions

USACE have requested that GH identify how factors such as water depth, wave height and wind speed can affect operation and maintenance (O&M).

GH consider access to be the primary O&M issue and the method of access has been listed in the tables. Most projects use or plan to use boat access although technicians are landed by heli-hoist on the nacelles of turbines at Horns Rev and this is an option offered by most turbine manufacturers. GH consider that Horns Rev is a special case because it has a particularly long transit time by boat from the service port. In general, considerations of safety, cost and accessibility appear to be leading operators to use some form of boat access.

To date, transfers of technicians from boat to turbine, which is the major access issue, have been by conventional ladder landings. However, the sites under construction and planned are mostly in more demanding wave climates and this method offers poor levels of safe accessibility. Hence, there are various different approaches under development to improve the access capability in bad weather.

In terms of scheduling of O&M work, all offshore projects plan their main scheduled or preventative maintenance activities in the summer season when weather is more reliably benign. Winter O&M will mostly be unscheduled and undertaken as the sea state permits access. Therefore, the service function at an offshore wind farm will typically be more heavily resourced in summer than winter.

Wind conditions are a limiting factor for lifting operations but this is not seen as a major consideration for O&M, which will typically only involve such operations in the event of major premature component failure.

For European projects, sea ice is only an issue in the Baltic Sea. This is mainly a design issue and the only project identified where specific measures have been taken for O&M work is Utgrunden, where the services of a small icebreaker are employed through the winter.

4.10 Manufacturers & contractors for major equipment supply and construction

These have been identified, where contracts are placed or under negotiation.

4.11 Economics

The criteria considered by GH are primarily technical. However, in wind power, it is impossible to consider technical and economic issues in isolation and specifically:

- The projects in Table 1 and 2 are, in practically all cases, of a demonstration nature and it is arguable that none should be considered as being a truly commercial development.

- The projects in Table 3 have not received economic sanction and therefore do not have construction contracts in place. They cannot be considered to have passed their main economic test, and hence may not be realised.

- No offshore wind farm has yet been financed by a non-recourse or limited-recourse construction loan. This financing model, which is anticipated to be a major tool for realising future offshore wind projects, will force contractors to carry additional construction risk, with consequent cost penalty to the project.

- Early projects will have benefited from capital grants and other state aid measures which may not be so readily available in the future.

From this, it can be concluded that no offshore wind farm project has yet exhibited “real life” costing. Hence, while the industry is clearly evolving technically, and more efficiently developing projects, the above factors will tend to slow moves to sites which are technically more onerous.

5 CONCLUSIONS

The work presented here has been undertaken for the US Army Corps of Engineers with the following findings:

1. A total of 23 wind farm projects have been identified, with total capacity over 2000 MW, which have been constructed recently or which GH consider certain or likely to come into commercial operation in the next 2 to 3 years.

2. For each of the offshore wind farm projects identified, the key project features and site characteristics have been identified, where available.

3. The survey has been aimed at providing a benchmark for the environmental assessment of the proposed Horseshoe Shoal site at Nantucket Sound.

Project	Blyth	Middelgrunden	Utgrunden	Yttre Stengrund	Horns Rev
Location	North Sea, N E England, UK	Baltic Sea, Copenhagen, Denmark	Kalmarsund, Baltic Sea, Sweden	Oland, Sweden	North Sea, Jutland, Denmark
Wind farm rated power	4 MW	40 MW	10 MW	10 MW	160 MW
Project owner	Blyth Offshore (Amec Wind; Powergen; Shell Renewables; NUON)	SEAS / E2 / Middelgrunden Co-operative	Developed by Enron (now GE) Wind	Originally owned by a Danish company Store Frederikslund. Sold last year to E2	Elsam, Eltra
Commercial operation date	Dec-00	Dec-00	Dec-00	2001	Nov-02
Contractors					
Turbine supply, O&M	Vestas	Bonus	Enron (now GE) Wind	NEG-Micon	Vestas
Foundation supply	Watson	Carl Bro, Monberg & Thorsen	Enron (now GE) Wind	AMEC	SIF
Electrical works	Global Marine	NKT, Siemens	Enron (now GE) Wind	ABB	Nexans, Alstom, ABB, Siemens
Marine installation	Amec Marine, Seacore	Pihl & Son	Hydro Soil Services (DEME)	AMEC (foundations, turbines), NEGM (cables)	MT Hojgaard, A2Sea, Mammet Global, GMS
Site wind regime					
Annual mean wind speed	7 to 8m/s at 60m	7.2 m/s at 50m	Not available	7.1 m/s at 60m MSL	9.7 m/s at 62m MSL
Comment (e.g. source)	GH/GL	SPOK ApS paper on website		NEG-Micon	Elsam A/S brochure 2002
Water depth					
Shallowest turbine LAT	6 m	4 m	8 m	7.5 m	6 m
Deepest turbine LAT	6 m	8 m	10 m	8.6 m	14 m
Tidal range	5 m	Negligible	Negligible	Negligible	Approx. 2 m
Wave climate					
Extreme wave (e.g. 50 yr Hs)	8 m	2.6 m	4 m	6.8 m (7.2m 100 yr)	Approx. 5 m
Substrate type	Rock	Sand and waste deposits overlying varying mixture of limestone and glacial deposit.	25m of glacial moraine (with boulders) overlying bedrock	Not available	Sand
Turbine information					
Make	Vestas	Bonus	Enron (formerly GE) Wind	NEG-Micon	Vestas
Model	V66-2MW	2MW	EWC 1.5	NM72/2000	V80
Rated power	2000 kW	2000 kW	1500 kW	2000 kW	2000 kW
Rotor diameter	66 m	76 m	70.5 m	72 m	80 m
No. of units	2 m	20 m	7	5	80
Hub height	58 m	64 m	65 m	60 m	70 m MSL
Conceptual foundation design	3.5m x 33m monopile with 15m rock socket	Reinforced concrete gravity base	Driven steel monopiles (34m long, 3.0m diameter, 19m embedment)	Drilled monopile	Driven monopile
Distance to nearest land	1 km	2 km	8 km	5 km	14 km
Distance to interconnection	1.5 km	2 km	8 km	6 km	0 km
Type of transmission line	11kV AC EPR 70mm^2	30kV AC 240mm^2	20 kV AC	20kV AC	150 kV AC
Access method	Boat	Boat	Boat	Boat	Helicopter and boat
Other comments		Occasional icing - design factor.			Utility connection is at wind farm substation platform
Sources of information	www.blyth-offshore.co.uk (2001)	www.middelgrunden.dk	Luc Vandenbulcke & Koen Van De Putte "The Utgrunden & Samsoe Offshore Wind Farm Project: Baltic experiences as a basis for the analysis of foundation and installation aspects", OWEMES 2003 Conference Proceedings (www.omemes.it).	NEG-Micon	Vestas and Techwise Seminar July 2002

Table 1 Projects constructed 2000 to 2002.

Project	Samso	Nysted	North Hoyle	Arklow Bank	Scroby Sands	Breitling
Location	Baltic, Paludens Flak, S of Samso, Denmark	Lolland, Denmark	Irish Sea, N Wales, UK	Irish Sea, Arklow, Ireland	North Sea, E England, UK	Germany, Baltic Sea
Wind farm rated power	23 MW	165.6 MW	60 MW	25.2 MW	60 MW	2.3 MW
Project owner	Samso Hawind A/S	Energi E2, DONG & Sydkraft	National Wind Power Offshore	Arklow Energy (GE Wind)	Powergen Renewables	Wind-Projekt GmbH
Commercial operation date	2003	2003	Sep-03	Autumn 03	2004	Anticipated 2003 or 2004
Contractors						
Turbine supply, O&M	Bonus	Bonus	Vestas and Mayflower Energy	GE Wind	Vestas	Nordex
Foundation supply	Bladt Industries	Aarsleff Ballast Nedam	Vestas and Mayflower Energy	GE Wind	Vestas	Local contractor
Electrical works	ABB	Not available	Vestas and Mayflower Energy	GE Wind	Vestas	Local contractor
Marine installation	Hydro Soil Services	Aarsleff Ballast Nedam, A2SEA	Vestas and Mayflower Energy	GE Wind	Vestas	Nordex
Site wind regime						
Annual mean wind speed	8.0 m/s at 60m	Approx 9 m/s	8 to 9 m/s at 60m	9.0 to 9.1 m/s at 60m	8.0 m/s at 60m	Not available
Comment (e.g. source)	GH/GL	Paper by Per Voelund & Lars Woller (EWEC 2003)	GH/GL	GH/GL	Powergen Renewables	GH/GL
Water depth						
Shallowest turbine LAT	11 m	6 m	5 m	2 m	2m	2 m
Deepest turbine LAT	18 m	9 m	12 m	5 m	10m	2 m
Tidal range	less than 1m	1 m	9 m	4 m	2m	< 1m
Wave climate						
Extreme wave (e.g. 50 yr Hs)	Not available	Not available	Not available	10 m (may be depth limited)	Not available	Not available
Substrate type	Not available	Strong clay till	Not available	Sand	Coastal sandbank	Harbour mud
Turbine information						
Make	Bonus	Bonus	Vestas	GE Wind	Vestas	Nordex
Model	Upgraded 2.0 MW	Upgraded 2.0 MW	V80	GE 3.6	V 80	N 90
Rated power	2300 kW	2300 kW	2000 kW	3600 kW	2000 kW	2300 kW
Rotor diameter	82.4 m	82.4 m	80 m	104 m	80m	90
No. of units	10	72	30	7	30	1
Hub height	68.8 m	68.8 m	67 m MSL	72 m MSL	60m MSL	80 m MSL
Conceptual foundation design	Driven monopile	Concrete gravity	Monopile (mixed driven & drilled)	Driven monopile	Driven monopile	Gravity
Distance to nearest land	3 km	6 km	8 km	12 km	2.5km	<1 km
Distance to interconnection	Not available	0 km	11km	12 km	2.5km	<1 km
Type of transmission line	Not available	132 kV cable to shore	33kV AC	38kV AC	33kV AC	20kV AC
Access method	Not available	Boat	Not available	Boat	Boat	Boat
Other comments		Utility connection is at wind farm substation platform	Under construction	Under construction	Fully connsented. Construction commences Jan 2003	Consented
				First phase of consented 520 MW development		
Sources of information	www.seas.dk	Paper by Per Voelund & Lars Woller (EWEC 2003)	www.natwindpower.co.uk/northhoyle/northhoyle.htm	www.airtricity.com; Arklow Energy	Powergen Renewables	Sonne Wind & Wärme 7/2003; Neue Energie 4/2003; Nordex;www.nordex-online.de; www.bsh.de; www.wind-projekt.de

Table 2 Projects contracted / under construction 2003 to 2004.

Project	Robin Rigg	Barrow	Burbo	Rhyl Flats	Kentish Flats	Gunfleet Sands	Inner Dowsing / Lynn	Thornton Bank
Location	Solway Firth, Scotland / NW England	Irish Sea, NW England, UK	Liverpool Bay, Irish Sea, NW England, UK	Irish Sea, N Wales, UK	Thames, England, UK	Thames, England, UK	North Sea, E England, UK	Belgium
Wind farm rated power	Max. 198 MW	90 to 100 MW	90 MW nominally	60 to 120 MW	90MW approx.	108 MW	90 MW	216 to 300 MW
Project owner	Offshore Energy Resources Ltd	Warwick Offshore Wind Limited (Warwick Energy)	SeaScape Energy Limited	National Wind Power Offshore	Global Renewable Energy Partners UK Marine Ltd (GREP)	GE Wind	Renewable Energy Systems and British Renewables / AMEC.	C-Power n.v. (Dredging International / Turbowinds / Interelectra / Socofe / Ecotech Finance)
Commercial operation date	Anticipated 2005	Anticipated 2004 or 2005	Anticipated 2005	Anticipated 2005	Anticipated 2005	Anticipated 2005	Anticipated 2006	Anticipated 2005 (earliest)
Contractors								
Turbine supply, O&M	To be determined	Vestas-KBR or GE Wind	To be determined	To be determined	Currently tendering	GE Wind	Not awarded	To be determined
Foundation supply	To be determined	Vestas-KBR or GE Wind	To be determined	To be determined	Currently tendering	Not awarded	Not awarded	To be determined
Electrical works	To be determined	Vestas-KBR or GE Wind	To be determined	To be determined	Currently tendering	GE Wind	Not awarded	To be determined
Marine installation	To be determined	Vestas-KBR or GE Wind	To be determined	To be determined	Currently tendering	Not awarded	Not awarded	To be determined
Site wind regime								
Annual mean wind speed	8.0 to 8.5 m/s at 60m	8.7 m/s at 60m	8.3 to 8.6 m/s at 60m	8.3 to 8.7 m/s at 60m	Approx 9.0 m/s at 80 m	8.6 m/s at 60m	8.5 m/s at 60m	8.8 m/s at 60m
Comment (e.g. source)	GH/GL wind map	GH/GL wind map	GH/GL wind map	GH/GL wind map	GREP	EIS	GH/GL wind map	GH/GL wind map
Water depth								
Shallowest turbine LAT	4m	15m	4 m	5 m	3m	Less than 1m	6m	10 m
Deepest turbine LAT	9m	20m	6 m	17 m	5m	6 m	13m	20 m
Tidal range	7m	8m	8 m	8 m	5m	4m	6m	4 m
Wave climate								
Extreme wave (e.g. 50 yr Hs)	10.7 m	Not available	7 m	Up to 5 m (measured)	2.7m	5 m	To be determined	6 m
Substrate type	Sub tidal bank composed of reasonably homogenous fine to medium sands with shell fragments, sediments overlie a layer of stiff clay with cobbles and boulders lying at depths of 8m to at least 29m below seabed	Up to 10m sands and silts overlying at least 30m glacial till overlying bedrock	Up to 15m of sands overlying strata of silts/clays/gravels, of boulder clay and of bedrock at 40m below seabed	Up to 20m of sandy gravelly clays overlying siltstone and mudstone	Sedimentary deposit over lime London clay	Sands overlying London Clay.	Shallow sloping thin bed of sand, gravel and shells, below lies a layer of clay.	Sandbank
Turbine information								
Make	Not awarded	Vestas or GE Wind	To be determined	To be determined	Currently tendering	GE	To be determined	To be determined
Model	Not awarded	V90 or GE 3.6	To be determined	To be determined	Currently tendering	GE 3.6	To be determined	To be determined
Rated power [kW]	Not awarded	3000 or 3600	To be determined	To be determined	Currently tendering	3600 kW	To be determined	3600 to5000
Rotor diameter [m]	Not awarded	90 or 104	90 m nominally	80 to 105 m	Currently tendering	104m	120m	To be determined
No. of units	60	30	30	30	30	30	30	60
Hub height	75 to 80 m MSL	70 to 80 m MSL	80 m nominally	60 to 100 m	80m max	76m MSL?	90m	To be determined
Conceptual foundation design	Driven/drilled monopile	Monopile (driven or drilled)	Monopile (driven or drilled)	Monopile 3.5m to 4.5m diameter, embedded up to 30 m into the seabed	Two monopile designs or gravity base, suction pile	Driven monopile	Driven/drilled monopile or gravity base	To be determined
Distance to nearest land	8 km	8 km	8 km	8 km	8 km	7 km	5 km	25 km
Distance to interconnection	12 km	27 km	12 km	9 km	12 km	8 km	8 km	30 km
Type of transmission line	2 x 132 kV AC	132 kV AC	Medium voltage (ca. 33 kV) AC	Medium voltage or high voltage AC	33 kV AC	132 kV AC	132 kV AC	150 kV AC
Access method	To be determined	Not available	Boat	Boat	Boat	To be determined	To be determined	To be determined
Other comments	Fully consented.	Fully consented.	Fully consented. Above information is "nominal" based on EIS	Fully consented. Above information is "nominal" based on EIS	Fully consented.	Fully consented.	Consents pending.	Consented.
Sources of information	Robin Rigg Offshore Wind Farm Environmental Statement - 2001	RSK Environment Ltd Barrow Offshore Wind Farm Environmental Impact Statement May 2002	SeaScape Energy Burbo Offshore Wind Farm Environmental Impact Statement Sept 2002	West Coast Energy Rhyl Flats Offshore Wind Farm Environmental Impact Statement March 2002	Information provided by GREP	Gunfleet Sands Offshore Wind Farm Environmental Statement 2002	Lynn Offshore Wind Farm Enviromental Statement - August 2002	www.c-power.be

Table 3 Projects planned for construction 2004 to 2006.

Project	NoordzeeWind	Q7-WP	Borkum West (pilot phase)	Butendiek	Wilhelmshaven	Baltic 1
Location	Netherlands	Netherlands	Germany, North Sea	Germany, North Sea	Germany, North Sea	Germany, Baltic Sea
Wind farm rated power	100 MW	120 MW	40 to 60 MW	240 MW	4.5 MW	48.3 MW
Project owner	NUON, Shell, Ballast Nedam, ING bank	E-Connect, Vestas, ABB, Fortisbank	Prokon Nord Energiesysteme GmbH	OSB Offshore-Bürger-Windpark Butendiek GmbH	Winkra-Energie GmbH	Wind-Projekt GmbH
Commercial operation date	Anticipated 2004 (partly, earliest)	Anticipated 2005 (earliest)	Anticipated 2005	Anticipated 2005 to 2006	Anticipated 2005	Anticipated 2004 or 2005
Contractors						
Turbine supply, O&M	NEG-Micon	Vestas	Not available	To be awarded Sept 03	Enercon	Nordex
Foundation supply	Ballast Nedam	To be determined	Not available	To be awarded Sept 03	Not available	To be determined
Electrical works	To be determined	ABB	Not available	To be determined	Not available	To be determined
Marine installation	Ballast Nedam	To be determined	Not available	To be awarded Sept 03	Not available	To be determined
Site wind regime						
Annual mean wind speed	9 m/s	Approx. 9 m/s	9.3 m/s at 80m	8.6 m/s at 60m	8.2 to 8.5 m/s at 60m	Not available
Comment (e.g. source)	Near Shore Feasibility study	Deduced from website	www.prokonnord.de	GH/GL	GH/GL	GH/GL
Water depth						
Shallowest turbine LAT	15 m	20 m	30 m	17 m	ca 0 m	17 m
Deepest turbine LAT	20 m	25 m	30 m	20 m	ca 0 m	18 m
Tidal range	2 m	1 m	ca 3-4m	ca. 1 m	ca 5 m	< 1m
Wave climate						
Extreme wave (e.g. 50 yr Hs)	Not available	Not available	Not available	10.4 m 100 yr extreme	Not available	> 8 m
Substrate type	Sandbank	Information not available	Fine sands, silts and clays overlying sandy sediments	Coherent sand.	Not available	To be determined
Turbine information						
Make	NEG-Micon	Vestas	Not available	NEG Micon, Vestas or GEWE	Enercon	Nordex
Model	NM92/2750	V80	Not available	NM92/2750, V90 or GE3.6	E-112	N90
Rated power [kW]	2.75 MW	2 MW	3500 to 5000	2750 to 3600	4500	2300
Rotor diameter [m]	92 m	80	Not available	90 to 104 m	112	90
No. of units	36	60	12	80	1	21
Hub height	ca 80 m	57m MSL	Not available	70 to 80 m MSL	100	80 m MSL
Conceptual foundation design	Monopile	Monopile	Tripod	Probably monopile but possibly tripod or jacket	Not available	Monopile
Distance to nearest land	8 km	23 km	50 km	34 km	550 m	< 19 km
Distance to interconnection	12 km	25 km	Not available	34 km	Not available	53 km
Type of transmission line			110 kV AC	380kV AC	Not available	150kV AC
Access method	Boat	Boat, Helicopter	Not available	Boat or helicopter options still being considered	Not available	Boat
Other comments	Consented.	Consents pending.	Second phase ca. 1000 MW 2006+. Pilot phase - wind farm consented; cable landing partially consented.	Wind farm consented; cable landing not yet consented.	Consented	Ice loading is a consideration
Sources of information	www.offshorewind.nl	www.e-connection.nl	Sonne Wind & Wärme 7/2003; Neue Energie 9/2001; Neue Energie 2/2003; Neue Energie 4/2003; www.prokonnord.de; www.bsh.de	Sonne Wind & Wärme 7/2003; Neue Energie 9/2001; www.butendiek.de; www.bsh.de; Developer.	Sonne Wind & Wärme 7/2003; Neue Energie 9/2001; www.winkra.de; www.bsh.de.	Sonne Wind & Wärme 7/2003; www.wind-projeky.de; www.bsh.de; Nordex.

Table 3 Projects planned for construction 2004 to 2006 - continued.

Project	**Cape Wind**
Location	Nantucket Sound, Massachusets, USA
Wind farm rated power	420 MW
Project owner	Cape Wind Associates
Commercial operation date	Anticipated 2005
Contractors	
Turbine supply, O&M	GE Wind
Foundation supply	To be determined
Electrical works	Pirelli
Marine installation	To be determined
Site wind regime	
Annual mean wind speed at hub ht	8.9 m/s at 75 m MSL
Comment (e.g. source)	Cape Wind Associates
Water depth	
Shallowest turbine LAT	4 m
Deepest turbine LAT	15 m
Tidal range	1 m
Wave climate	
Extreme wave (e.g. 50 yr Hs)	5 m (local), <12 m (ocean wave, subject to depth limiting)
Substrate type	Sands, silts, gravels
Turbine information	
Make	GE Wind
Model	GE 3.6
Rated power	3600 kW
Rotor diameter	104 m
No. of units	130
Hub height	75m Low water
Conceptual foundation design	Driven monopile
Distance to nearest land	8 km
Distance to interconnection	29 km
Type of transmission line	115 kV AC
Access method	Boat
Other comments	
Sources of information	www.capewind.org, CapeWind Associates

Table 4 Cape Wind Nantucket Sound site.